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ON THE POSSIBILITY OF INVESTIGATION OF PRIMARY COSMIC
RADIATION BY TRACKS OF NUCLEAR PARTICLES IN
METEORITES AND TEKTITES

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ON THE POSSIBILITY OF INVESTIGATION OF PRIMARY COSMIC
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SUMMARY

It is shown that the investigation of primary cosmic radiation by the tracks of nuclear particles in meteorites and tektites is possible on the basis of the study of the depth of tracks and the results of measurements of the age of tektite hardening.

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* *

When heavy charged particles traverse hard dielectric bodies, they form over their path traces of disruptions which may be treated with a mordant and revealed with the aid of the optical microscope [1]. The parameter determining the possibility of detecting tracks of such particles in a given substance is the mean specific energy loss by the particles $(dE/dx)_{crit}$ [2]. This allows us to identify the nuclei forming these tracks by their charge, which may be utilized during the investigation of the intensity of the heavy particles of cosmic radiation.

Helium and hydrogen nuclei being the main component of the primary radiation, do not form tracks. This is why the very weak fluxes of nuclei with $Z \geq 14 : 15$ ($I = 0.4 \div 0.5 \text{ m}^{-2} \text{ ster}^{-1}$) [3] may be measured with the aid of a mica detector placed on artificial satellites of the Earth. The absence of background tracks from α -particles in natural minerals allows us to register the small density of tracks resulting from fragments of spontaneous fission of uranium, having accumulated in samples in the course of geological epochs, determining by the same token the age from the moment of sample's cooling to a temperature below the $200-300^\circ$ range. The study of tracks' formation and preservation in tektites at various temperatures and pressures has shown [4] that the tracks do not disappear in the course of unlimited time at heating up to 200° inclusive.

* O VOZMOZHNOСТИ ISSLEDOVANIYA INTENSIVNOSTI PERVICHNOGO KOSMICHESKOGO IZLUCHENIYA PO TREKAM YADERNYKH CHASTITS V METEORITAKH I TEKTITAKH.

When investigating the tracks of charged particles in meteorites it was found to be possible to determine the age of meteorite matter hardening [5]. Moreover, by way of registration of V-shaped tracks that may be forming under the action of high-energy protons of primary cosmic rays, the age of tektite occurrence in interplanetary space could be determined.

Following could be the sources of tracks in meteorites:

- a) fragments of spontaneous fission of U^{238} and Pu^{244} [5];
- b) induced fission under the action of primary cosmic ray protons;
- c) uranium fission under the action of neutrons formed during splitting reactions in meteorite matter;
- d) recoil nucleus of these reactions, and
- e) nuclei with $A \geq 30$ entering into the composition of cosmic rays.

We investigated four samples of tektites: three moldavites and one philippinite. The method amounted to the preparation of spallation fragments, which were treated with a mordant of 40% HF in the course of 3 to 5 minutes; these samples were then examined under an optical microscope in direct and reflected light.

The results of age measurements of tektite hardening are compiled in Table 1. The age of tektites (T), during which spontaneous fission tracks with density ρ_{cfn} were stored, is determined by formula

$$T = \frac{\rho_{\text{cfn}}}{N_0 C_U \lambda_f R \cos^2 \theta_c},$$

where N_0 is the number of uranium atoms in 1 cm³ of sample, borrowed from [7] (for moldavites it is $2.1 \cdot 10^{-6}$ g/g. and for philippinites it is $1.8 \cdot 10^{-6}$ g/g); C_U is the atomic concentration of U^{238} ; λ_f is the U^{238} spontaneous fission constant, equal to $8.27 \cdot 10^{-17}$ years⁻¹; R is the mean effective path of fission fragments that may be detected by mordant treatment in tektites, equal to $1.2 \cdot 10^{-3}$ cm [8]; θ_c is the critical angle of track mordant treatment, equal to 30° for tektites [8].

For the sake of comparison data of K-Ar method of tektite age determination related to the groups of moldavites and philippinites are brought up in Table 1 (see [9]). For the first ones a good age agreement was obtained, despite their being determined by two independent methods. The sample of philippinite, having revealed a lower age by comparison with the data of the K-Ar method, may possibly have undergone a significant heating at a later time after hardening.

During interaction of primary cosmic radiation protons with nuclei of tektite matter, secondary neutrons may be forming in splitting reactions, during the trapping of which uranium and thorium nuclei undergo fission. Moreover, in the process of ablation on account of heating of the thin superficial tektite layer the density of the tracks may also vary with depth. For the estimate of the possible contribution of the indicated effects, the fission fragments' track density dependence in depth on the surface of tektites was investigated.

The results are plotted in Fig.1. There is observed in the superficial layer of ~ 1 mm thickness a nearly identical character of that dependence for the three samples of moldavites. Within the limits of measurement errors the density of tracks in the moldavite sample No.181 is constant, whereas for samples No.112 and 159, a small rise is observed.

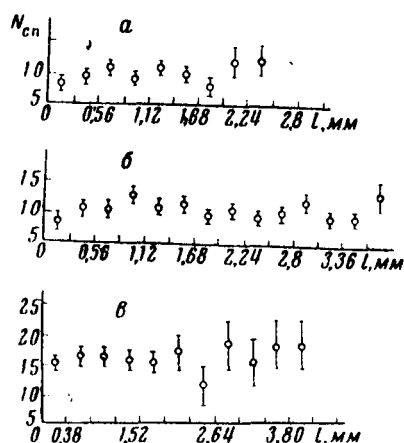


Fig.1

When examining the mordant-treated surfaces of tektites, there are observed cases of tracks which may be referred to cases of triple fission. The probability of appearance of these tracks, which may possibly be evidence of induced fission into three fragments under the action of high energy protons of cosmic rays, constitutes $\sim 10^{-3}$ of the total number of tracks of spontaneous uranium fission. Having taken into account that the ratio of probabilities of spontaneous fission of heavy nuclei into three to two fragments constitutes $\sim 10^{-4}$ [10], we shall obtain for the density of triple tracks

$$\rho_{tp} \approx 10^{-4} \rho_{cn} \approx 1 \text{ per } 1 \text{ cm}^2$$

or $\sim 10\%$ of the observed density $\rho_{tp} \approx 15$ per 1 cm^2 in tektites.

TABLE 1

Measured Age of Tektite Hardening

Sample	Area considered mm^2	Number of tracks	Density of tracks per 1 cm^2	Age ($\cdot 10^4$ years)	
				by tracks*	K - Ar
Moldavite No.112	7.89	1157	14650 ± 430	15.7 ± 0.5	15
No.159	11.81	1835	15000 ± 360	16.0 ± 0.4	
No.181	10.14	1975	14110 ± 330	15.1 ± 0.3	
Philippinite	25.6	36	141 ± 23	0.2 ± 0.03	0.7

* The error for T is defined as the statistical error of ρ_{cn} measurement

A more precise calculation of ρ_{cn} will allow us to determine the time T_p of tektite occurrence in interplanetary space, which may be expressed as $T_p = \rho_{tp} / \Phi_p w$. Here Φ_p is the global flux of primary cosmic rays equal to $2.9 \text{ particles} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1} \cdot (4\pi \text{ ster})^{-1}$ [11]. The rate of formation of triple tracks by high energy protons, w , may be determined in model experiments with the aid of a proton accelerator.

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